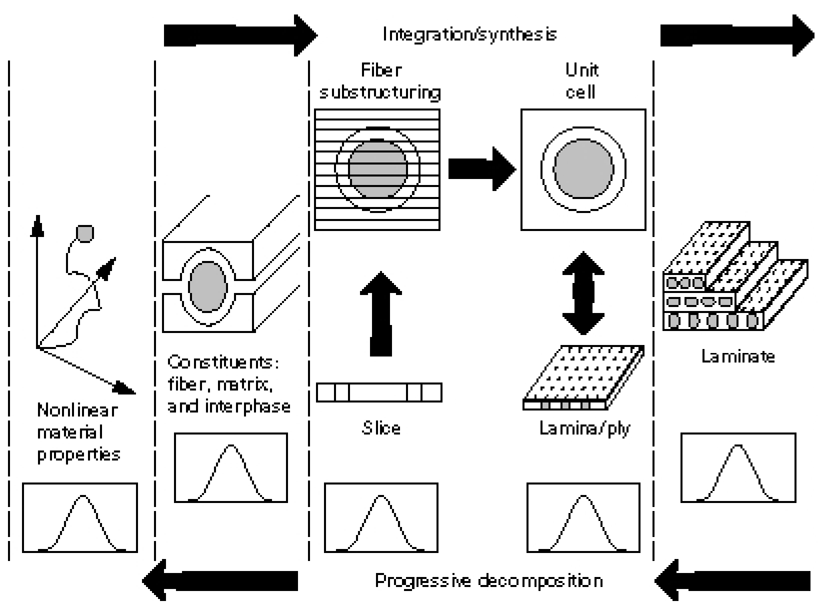
Micromechanical Modeling Efforts for Advanced Composites

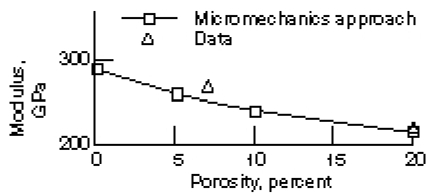
Over the past two decades, NASA Lewis Research Center's in-house efforts in analytical modeling for advanced composites have yielded several computational predictive tools. These are, in general, based on simplified micromechanics equations. During the last 3 years, our efforts have been directed primarily toward developing prediction tools for high-temperature ceramic matrix composite (CMC's) materials. These materials are being considered for High Speed Research program applications, specifically for combustor liners. In comparison to conventional materials, CMC's offer several advantages: high specific stiffness and strength, and higher toughness and nonbrittle failure in comparison to monolithic ceramics, as well as environmental stability and wear resistance for both room-temperature and elevated-temperature applications. Under the sponsorship of the High Temperature Engine Materials Program (HITEMP), CMC analytical modeling has resulted in the computational tool Ceramic Matrix Composites Analyzer (CEMCAN). This code was released through COSMIC (NASA's software distribution center) recently.

The analysis of CMC materials requires specialized modeling that considers their unique physical and mechanical behavior. Ceramic matrix composite materials are reinforced primarily to enhance toughness because the matrix material is quite brittle and fails at relatively low strain levels. The methodology incorporated in CEMCAN is based on micromechanics models in which, customarily, a representative volume element or unit cell is arranged in a square array pattern. However, the present approach employs a unique multilevel substructuring technique that allows the capture of greater local detail. The methodology also takes into account fracture initiation and progression, as well as nonlinear composite behavior due to temperature.



Integrated probabilistic ceramic matrix composite mechanics approach.

Unlike conventional materials, CMC's exhibit a considerable amount of scatter in the material properties. Since these materials must sustain a reliable life of several thousand hours in High Speed Civil Transport propulsion systems, prediction tools must be developed to account for uncertainties in the material behavior and fabrication parameters. Currently, work is underway to incorporate probabilistic analysis in the micromechanics and macromechanics of CMC's. In addition to providing more formalism to the analysis as opposed to the conventional "safety factor approach," such procedures will enhance interpretation of experimentally measured properties that have a wide range of scatter. Furthermore, the procedure will help identify the variables that influence the response most, thereby providing guidelines for quality control during the fabrication process of these materials.



In-plane modulus versus porosity (SiC/SiC composite; fiber volume ratio, 0.4).

Another area of growing interest in the composite community is the use of woven or textile composites for a variety of structural applications. For example, plain- and satin-weave constructions are being considered for combustor liners in the Enabling Propulsion Materials program, and woven polymer matrix composites are being considered for lower temperature applications in the Advanced Subsonic Technology program. Woven composites are constructed by weaving two fiber tows together to form a layer. The interlacing of fiber bundles has several advantages, such as increasing the intralaminar and interlaminar strength, providing greater damage tolerance, and providing a possible way to produce near-net shapes for thick structural components. A micromechanics-based approach for analyzing plain-weave ceramic and polymer matrix composites, which was recently developed in-house, is being integrated into NASA Lewis' composite mechanics computer codes.

Bibliography

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